Title: Under Pressure

Brief Overview:

This unit will explore the relationships between temperature and pressure, as well as between volume and pressure. Air will be trapped in a flask with a two hole rubber stopper. A syringe and a temperature probe will be attached. The students will vary both the volume (using the syringe) and the temperature (using hot and cold water baths) of the air. Data will be collected using the TI-8x series calculator and the CBL via the Vernier program CHEMBIO.

Links to NCTM Standards:

- **Mathematics as Problem Solving**
  Students will make predictions, collect data and then compare the actual results against those predictions. Various parameters will be manipulated with an eye towards calculating results.

- **Mathematics as Communication**
  Students will share their observations, calculations, and conclusions in both oral and written forms.

- **Mathematics as Reasoning**
  Students will draw conclusions form observation and from data collection. These conclusions will take the form data interpretation, graphical analyses, and mathematical modeling.

- **Algebra**
  Students will discover/revisit the inverse and direct relationships between measured variables. Also, linear regression and curve fitting techniques will be used. Predictions through math models will be made and conclusions drawn.

- **Functions**
  Students will discover the functional relationship between pressure and volume and between pressure and temperature. Students will also investigate the possibility of a functional;l relationship between volume and temperature.

Grade/Level:

10 (gifted) - 12 Chem/AP Chem

Duration/Length:

2 - 4 days depending on ability/period length/depth or breadth of discussion

Prerequisite Knowledge:

Students should have working knowledge of the following skills :

- Algebra I through functional relationships (linear, direct, inverse)
- Use of graphing calculator for data manipulation with lists
- Understanding of molecular the theory of gasses
- Standard lab procedures and equipment handling

Objectives:

Students will:

- learn to collect real-time data with the calculator based laboratory (CBL) and TI-8x calculator.
- understand the relationships that exist between volume, temperature and pressure of gasses.
- be able to model mathematically the data relationships.
- be able to interpret, interpolate, and extrapolate data from these models.

Materials:

- TI8x Calculator with link cable
- Calculator Based Laboratory (CBL)
- Vernier direct connect temperature probe with DIN adapter
- Vernier pressure sensor with syringe, rubber stopper assembly and DIN adapter
- Vernier Chemistry with CBL™ software
- TI Graph-Link™ software (optional)
- Ice

- 125 mL Erlenmeyer flask
- 4 - 1 liter beaker
- 100 mL beaker
- Ring stand with utility clamp
- Glove
- Vernier Graphical Analysis™ software (optional)
- Hot plate
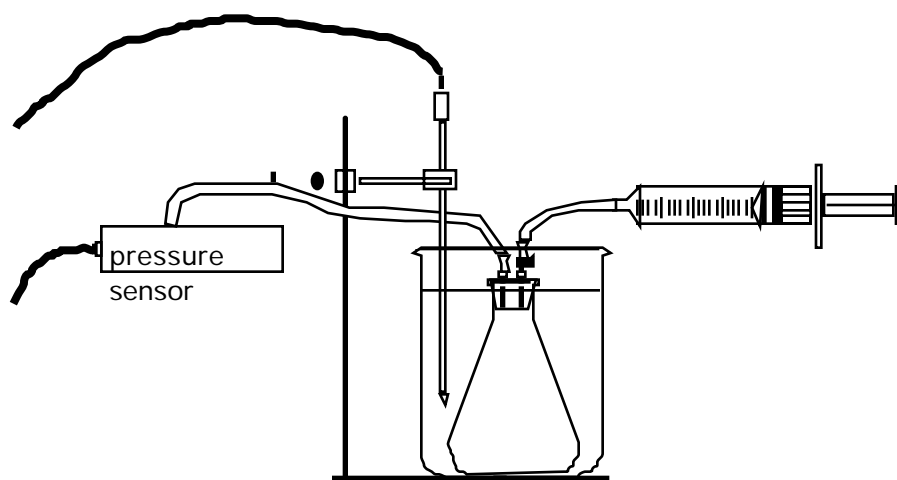- Goggles

Development/Procedures:

Figure 1

1. Wear goggles.

2. Prepare a boiling water bath. Put about 800 mL of hot tap water in a 1-L beaker and place it on a hot plate.

3. Prepare an ice water bath. Put about 700 mL of cold tap water into a second 1-L beaker and add ice to the 800 ml mark.

4. Put about 800 mL of room temperature water into a third 1-L beaker.

5. Put about 800 mL of hot tap water into a fourth 1-L beaker.

6. Prepare both the temperature probe and pressure sensor for data collection
    - the pressure sensor comes with a rubber stopper assembly all ready to collect data; insert the stopper with its two connectors into the flask
    - attach the pressure sensor box to the connector without the valve.(see figure 1)
    - expel all air from the syringe, follow the directions that are enclosed with the pressure sensor to be certain the valve is closed to the flask, then attach the syringe to that valve.(see figure 1)
    - attach the pressure sensor box to a DIN adapter and plug into channel 1 of the CBL.
    - attach the direct connect temperature probe to the ring stand, connect to a DIN adapter, plug into channel 2 of the CBL.

7. Turn on both the CBL and the TI8x.

8. Prepare the data collection system for use with the two probes
    - Start the CHEMBIO program on the TI8x and proceed to the main menu.
    - Select 1: SET UP PROBES (The CBL screen should now show   - - -   ).
    - Enter "2" for number of probes, Select TEMPERATURE, enter "2" for channel number.
    - At the calibration menu choose 3: USE STORED.
    - Select PRESSURE, enter "1" for the channel number, USED STORED for calibration and "ATM" for pressure units.

9. Prepare the system for data collection
    - Select COLLECT DATA from the main menu.
    - Select TIME GRAPH, 10 seconds between, 12 samples (120 seconds).
    - Select USE TIME SETUP.
    - Enter "0" as Ymin, "100" as Ymax, and "5" as Yscl.
    - Press ENTER to begin collecting data.

10. Wait 20 seconds, then lower the flask into the near boiling water bath. Allow the system to collect temperature versus pressure graph for the entire 2 minutes. Make a sketch of this graph. Use your arrow keys to trace the graph and observe the data points.

11. When the graph is completed, press ENTER, select "No" to not repeat collection. then "Quit". Press STAT, EDIT to view the data pairs in L1 and L2. Record these data pairs

12. Return to MAIN MENU of the CHEMBIO program. Reset your probes and this time select MONITOR from the DATA COLLECTION menu.

13. Open the valve to the syringe. (the plunger should move due to the change in pressure observed earlier). Record the syringe volume and the pressure/temperature monitored on the CBL.

14. Move the plunger in 5 mL increments and record the pressure and temperature pair monitored on the CBL along with each new volume. Close the valve to the syringe.

15. Remove the flask from the bath and allow to return to room temperature.

16. Repeat steps 7 through 15 for each of the remaining water baths.

17. Transfer pressure and temperature data from Table 1 to the TI8x.
- Press STAT on the TI8x and select EDIT from the menu. A table will appear.
    - **To clear a list of previous data:**
        - Using arrow keys place the curser in the heading of the list, press
        - Repeat for each list with data.
- Using arrow keys, position the curser in column L1. Begin entering temperature values pressing ENTER or the down arrow after each value.
- Repeat with column L2 entering pressure values.
- Press 2nd, Y= on the TI8x (STAT PLOTS screen appears) then select 1: Plot 1
- From the Plot 1 screen, select the following settings: Plot 1 = On, Type = scatter plot, Xlist = L1, Ylist = L2, and Mark = your choice
- To plot the graph of temperature versus pressure, press ZOOM then 9:Zoom Stat. Copy this graph. **Label.**
- Press STAT, arrow to CALC, select LinReg. to find the best line of fit. Transfer this regression equation into the Y= screen by pressing Y=, clear any current equation from Y1, then press VARS, select 5:Statistics, arrow to EQ, select RegEq. This will transfer the regression equation into Y1.
- Press GRAPH to see the statplot and the equation together. Record your regression equation and sketch the model on the previous graph.
- OPTIONAL: Use the TI Graph-Link or Graphical Analysis software to transfer the graph to a computer, **LABEL**, and obtain a printout.
- Repeat all of #17 for each of the water baths.

18. Follow the procedure outlined in #17, this time using the volume and pressure as L1 and L2 respectively. Do this for each temperature.

19. Turn in completed data tables, calculations sheet, and any graphs. **Clean up**.

Resources and References

- Vernier Software
  8565 S.W. Beaverton - Hillsdale Highway
  Portland, OR 97225-2429
  (503) 297-1760

    - Vernier Chemistry with CBL™ - Experiments using Vernier Probes and Sensors with the CBL System and the TI-82 Graphing Calculator, Dan D. Holmquist, et.al.; 1995
    - Graphical Analysis Software

- Texas Instruments Inc.

Extension/Follow Up:

1. Pick any three pressure volume pairs for each temperature and show that for that temperature PV/T is a constant.
2. The experiment could be repeated using different gasses, (e.g. He, CO_2)
3. A more detailed discussion on the significance of multiple trials versus pooled group data. Statistical analyses including measures of central tendency and dispersion could be included.
4. Have students calculate the volume of gas confined in the assembly.

5. Discuss with the students the validity of a pressure versus volume relationship even though this relationship was not directly observed.

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Worksheet 1
Temperature vs. Pressure

Boiling Water Bath

Time (sec)	Temperature	Pressure
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		
110		
120		

Hot Tap Water Bath

Time (sec)	Temperature	Pressure
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		
110		
120		

Worksheet 1
Temperature vs. Pressure

Room Temp. Water Bath

Time (sec)	Temperature	Pressure
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		
110		
120		

Ice Water Bath

Time (sec)	Temperature	Pressure
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		
110		
120		

Worksheet 2
Volume vs. Pressure

Boiling Water Bath _____°C

Pressure	Volume

Hot Tap Water Bath _____°C

Pressure	Volume

Worksheet 2
Volume vs. Pressure

Room Temp Water Bath _____°C

Pressure	Volume

Ice Water Bath _____°C

Pressure	Volume

Teachers Notes:

1. Fill each 125 mL Erlenmeyer flask with water to the base of the stopper assembly. Measure the water contained by pouring it into a graduated cylinder.

2. If time is limited you may wish to collect only the first part of the data. Or perhaps only one warm and one cold bath. Another option may be to divide the class into groups and have each group collect data for one bath only. Data then can be shared.

3. Prepare the assembly before hand for those classes where time is limited or ability is in question.

4. Try replacing the air in flask with other gasses and repeat. Try varying the amount of gas by adding/removing via the syringe